Response Time Improvement of OCB mode TFT-LCDs by using Capacitively Coupled Driving Method

Kenji Nakao

Display Device Development Center
Matsushita Electric Industrial Co., Ltd.
3-1-1, Yagumo-Nakamachi, Moriguchi, Osaka 570-8501, Japan
*Development Department, Liquid Crystal Display Division
Matsushita Electric Industrial Co., Ltd.
26-2, Kawakita, Nomi, Ishikawa 923-1296, Japan

ABSTRACT

We have developed a super-fast response OCB (Optically self-Compensated Birefringence) mode TFT-LCD by using capacitively coupled method driving (CC driving method). This driving method utilizes capacitively coupled voltage (CC voltage), and the voltage is applied to pixel electrodes through storage capacitors formed between preceding scanning line and the pixel electrode. Response times with this driving method are improved by the twice or more compared with those of a conventionally driven TFT LCD.

INTRODUCTION

Progress in LCD technology has produced high-contrast and wide-viewing angle LCDs. However Current LCDs have a drawback in that rapid movement tends to become blurred. In this respect, the LCDs are inferior compared with CRT.

Among practical display modes so far proposed, only the OCB mode can provides advantages of simultaneous fast response and wide viewing angle as well as relatively little modification needed to the conventional LCD panel manufacturing process.

It is reported that even in the OCB mode, the response time in the conventional TFT drive is longer than that in a static drive, due to dielectric anisotropy of liquid crystal material [1]. In addition, applying a blank picture in every frame cycle is effective to realize a high-quality motion picture display without blurring or ghosts [2,3,4]. It is necessary to speed up the response of the liquid crystal to achieve this driving which needs high filed frequency.

The CC driving method utilizes the capacitively coupled voltage which is applied to the pixel electrode through the storage capacitor formed between the preceding scanning line and the pixel electrode. It had been reported that this driving method was effective to improve the optical response time of TN-LCD, compared with the conventional TFT driving [5,6].

In this paper, we show the effect of using the CC driving method to the OCB-TFT-LCD and its display performance.

THEORY

A example when the display state changes from black state (at high voltage V0) into white state (at low voltage V100) is explained here.

Figure 1 shows an equivalent circuit of the pixel with conventional TFT driving method. A storage capasitor (Cst) is formed between a Vcom and a pixel electrode. Clc and Cgd are capacitance of the liquid crystal and parasitic capacitance between gate and drain respectively.

When a pixel voltage Vp is applied to the pixel electrode using the conventional TFT driving method, potential of the pixel electrode changes from Vp into Vp' which is shown in equation 1, because the potential charge of the pixel electrode changes with Clc in hold period.

$$Vp' = \frac{Cst + Clc(V0)}{Cst + Clc(V100)} Vp \qquad \cdots\cdots(1)$$

The Vp' is larger than the Vp, because of $Clc(V100) < Clc(V0)$. Excessive of this voltage leads the lack of

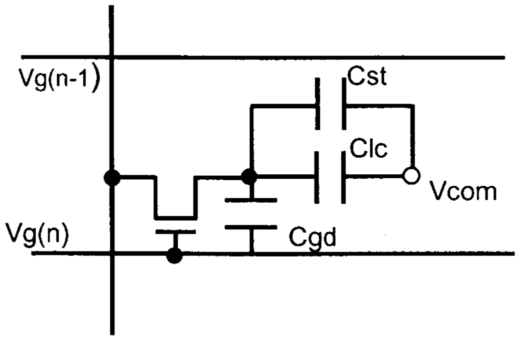

Figure 1. Equivalent circuit of the pixel using the conventional TFT driving method

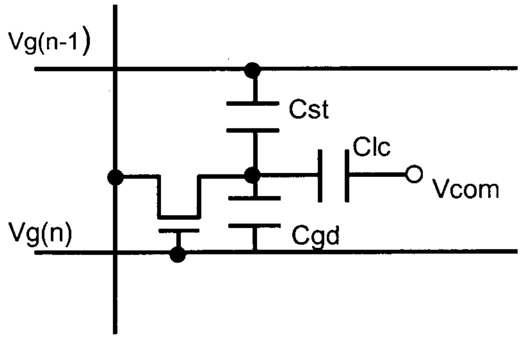

Figure 3. Equivalent circuit of the pixel using the capacitively coupled driving method

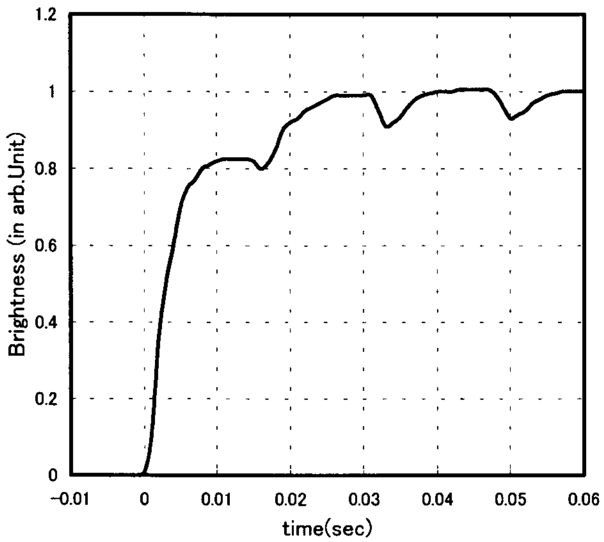

Figure 2. Optical response waveform of OCB panel using conventional driving.

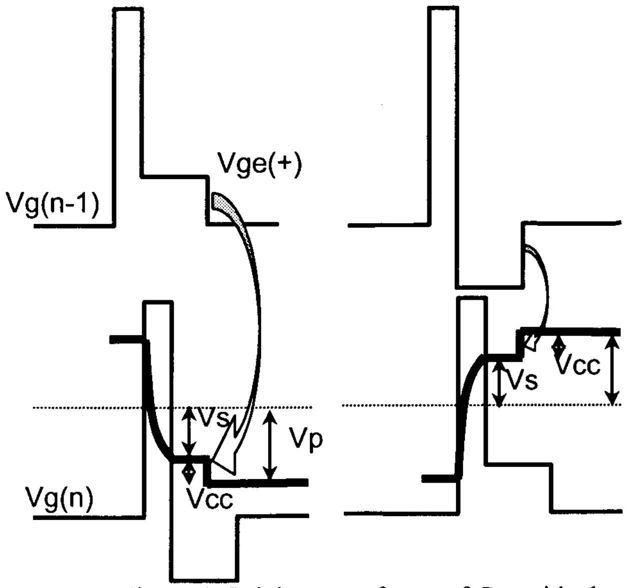

Figure 4. Driving waveforms of Capacitively Coupled Driving Method.

the brightness, and shape of the response waveform becomes shape shown in Figure 2 as a result. As shown in this figure, the response is not completed in one frame and it seemed as if the response time has slowed. It is effective to add some complementary voltages to supplement the decrease of the response time.

When the CC driving method is used, the conplementary voltage is added as follows. The CC driving method is closely concerned not only with driving schemes but also with TFT circuit. Figure 3 shows an equivalent circuit of the pixel using CC driving method. In the each pixel, a storage capasitor (Cst) is formed between a preceding scanning line(Vg(n-1)) and a pixel electrode. Figure 4 shows basic driving waveforms of the potensials of the scanning lines and the pixel electrode. This driving method involves four gate voltage levels, including the ON and OFF of TFT and two bias voltage (Vge(+) and Vge(-)). After charging the pixel electrode, the CC voltage is supplied to the pixel electrode through the storage capacitor by feedthrough effect of the two bias voltage Vge(+) or Vge(-) of the preceding scanning line.

Pixel Voltage Vp can be expressed as follows.

$$Vp = \pm Vs + \frac{Cst}{Cst + Cgd + Clc}(Vge(+) or Vge(-)) \qquad \cdots\cdots(2)$$

Where Vs is source voltage and the second term of eq.(1) is defined as capacitively coupled voltage Vcc.

It must be noted that the CC voltage depends on the Clc and the dielectric anisotropy of the liquid crystal material. And the Clc depends on the voltage which is applied to the liquid crystal. Table.1 shows the Clc at V0 and V100 and Cst of the OCB panel.

The pixel voltage in the CC driving method is written as eq.(2). When the pixel voltage changes from V0 to V100, the CC voltage Vcc is defined by using the Clc(V0) at first, and the Clc(V0) is larger than the Clc(V100). Since pixel addressing time is very short compared with the response time of the liquid crystal material, the change of the dielectric constant of liquid crystal can be neglected during pixel addressing.

In succeeding hold period, the dielectric constant of liquid crystal changes from Clc(V0) to Clc(V100). As the Clc(V100) is smaller than the Clc(V0), the CC voltage initially supplied to the pixel is lower than that in the late hold period. Thus the pixel voltage shows undershoot and it is settled to Vp.

For opposite change of the brightness (for instance, from V100 to V0), the capasitively coupled voltage applied at the addressing time is higher than that at hold time. In this case the pixel voltage shows overshoot. Therefor, by using this driving method, the conplementary voltage is automatically added as overdrive (overshoot or undershoot) whenever the pixel voltage is changed. This dynamic overdrive effect is expected to improve the optical response time of liquid crystal panel.

Table 1. Design parameters of the prototype 39cm-diagonal OCBmode TFT LCD

	parameters
Clc(V0)	0.76 pF
Clc(V100)	0.61 pF
Cst	0.44pF

RESULTS

We have developed a prototype 39cm (15.2 inch) diagonal wide TFT-LCD using the CC driving method. Its parameter is shown in table 1. In this case, the conplementary voltage was about 15% of the applied voltage.

Figure 6 shows response times ($\tau = \tau$ rise+ τ decay) measured between every two combinations among 5 brightness levels compared with the static driving, where "1" is the darkest state and "5" is the brightest state.

With static driving, a response time between black level and white one was 7ms. Using the CC driving method, a response time between black level and white one was 3ms, and response times between every gray scale levels are faster by the twice or more compared with the static driving. This OCB panel

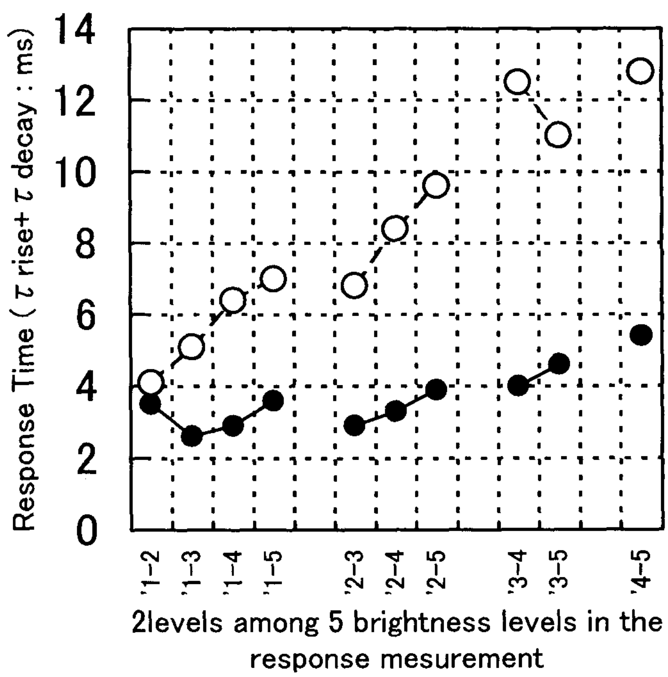

Figure 6. Comparison of the response time of OCB mode TFT-LCD using capacitively coupled driving with that of OCB panel using static driving .

shows a fast response of less than 6 ms even between gray scale levels.

In the OCB mode LCD, a wide viewing angle and a fast response are both achieved. Also we have developed newly designed compensation films, and achieved a wide viewing angle characteristic of 160 degrees horizontally and 120 degrees vertically under the condition of that the contrast ratio is over 10. Table 2 shows specification of this display.

CONCLUSION

We have developed a super-fast response OCB (Optically self-Compensated Birefringence) mode TFT-LCD by using CC driving method. Response times with this driving method are improved by the twice or more compared with the conventional TFT driving method.

It is suggested that this display device is useful for a high filed frequency LCD and a color field sequential LCD.

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Table 2. Specification of the prototype 39cm-diagonal OCBmode TFT-LCD

	Specification
Pixel Format(pixel)	854×480
Pixel Pitch(mm)	0.393×0.393
Number of Color	Full Color
Contrast Ratio	250:1
Response time (ms) [B-W levels]	3
Response time (ms) [Gray scale levels]	6
Viewing Angle(deg) [Vertical]	120
Viewing Angle(deg) [Holizontal]	160

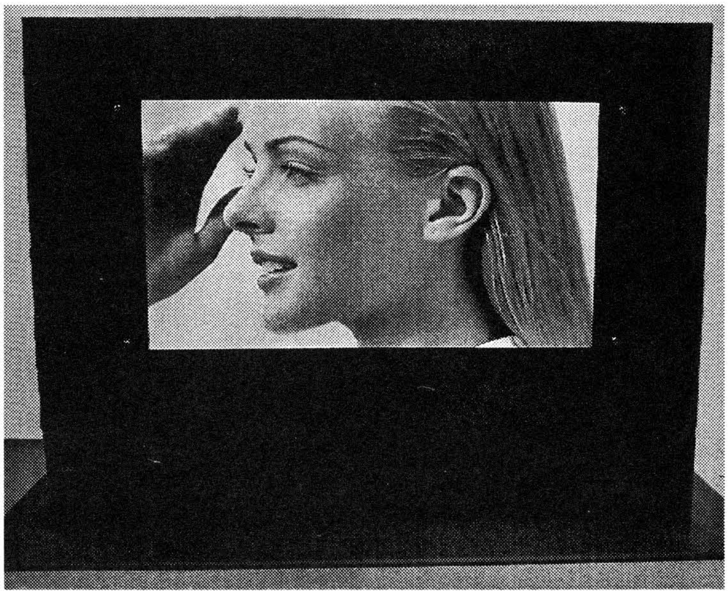

Figure 7. Photograph of the prototype 39cm-diagonal OCBmode TFT LCD